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Traffic Noise Barrier Design for Sound Transmission

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ABSTRACT

Noise barriers using corrugated steel panels may transmit significant levels of noise through the walls, so that receivers behind the barriers may perceive small increases in noise levels above the levels defracted over the edges of the barrier.

The paper presents a method of taking sound transmission through barrier walls into account. The value of noise abatement or insertion loss of barriers, as calculated by various prediction methods, is degraded or diminished by an "effective sound transmission loss", a new concept which is discussed.

A method is shown of determining the "effective sound transmission loss" for any particular panel material, based on 1/3 octave band frequency values of sound transmission losses as obtained from standard laboratory tests. It is shown that the effective value of sound transmission loss depends on these test results and the (1/3 octave band) frequency profile of prevailing traffic. If this traffic noise profile is A-weighted, then the resulting effective sound transmission loss is also A-weighted. Surprisingly, it is independent of the path length difference, i.e., the geometry of the barrier and the receiver, or source locations. Values have been calculated for several panels used in Ontario based on a typical expressway traffic spectrum (Highway 401, Toronto Bypass).

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1/ INTRODUCTION

Noise barrier design in the past has not taken into account the actual quantities of sound transmitted through the barrier wall, which can reduce the effectiveness of the barrier. In order to accommodate the least expensive wall material, namely corrugated steel panels, low minimum values for area densities were recommended [1] and specified. Arguments for these kind of decisions were based on the assumption that the sound transmission losses would be sufficiently high so that the noise transmitted through the barrier can be safely neglected compared to the higher noise diffracted over the top of it. Derivations were usually based on random or field incident mass laws, which are reasonably accurate for flat steel sheets. However, laboratory tests on corrugated steel panels have revealed significant "dips" in sound transmission loss profiles at critical medium frequencies between about 250 to 2000 Hz. The result is that sound transmission losses can be much lower than those estimated merely on the basis of incident mass laws. Thus, transmitted sound can be significant, especially for the more effective high barriers and for receiver locations close behind the barriers.

Instead of increasing the requirements for minimum area densities, which could exclude some very economical solutions with thin corrugated steel panels, it is preferable to take sound transmission into account whenever noise reduction values are calculated and quoted. To make up for the loss in barrier effectiveness due to sound transmission, it is also possible to determine additional barrier heights when thin steel panels are used. Compared to concrete barriers, thin steel barriers may need to be built higher in order to achieve some noise reduction. Although it is not easy to determine height equivalencies, a simple procedure can be used, as presented in Chapter 3 of this report.

The most difficult problem of incorporating sound transmission into a noise prediction method for noise barriers is to determine the effect of sound transmission loss for various panel materials. How can we determine an effective over-all value of sound transmission loss? Once such a value is determined, we can incorporate it into current prediction methods, as described in References 1 and 2.

The effective value of sound transmission loss has to be established by carefully tracing the over-all effect from the following items:

1/ The sound transmission losses for all 1/3 octave frequency bands over an effective range of band frequencies.

2/ A typical A-weighted traffic noise spectrum over the same range of frequencies.

3/ Attenuation due to diffraction, again over the same range of 1/3 octave band frequencies.

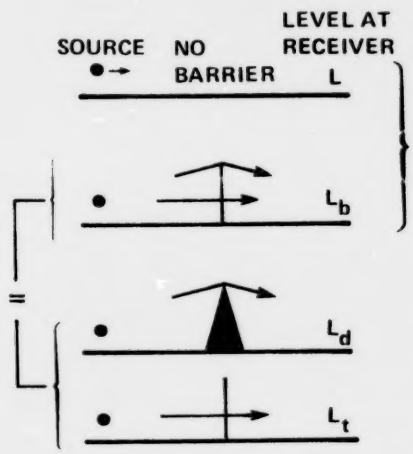
4/ The ground cover effects, also to be established over the same range of frequencies.

5/ The effect of the barrier wall acting as a new noise source for trans mitted sounds propagating towards the receiver by a shorter distance than from the source of traffic noise, as described in [4].

It should be noted that items 4 and 5 are not yet part of any prediction method currently used in Ontario, in terms of an analysis based on 1/3 octave band frequencies. Item 4 has been taken into account in various methods, in the sense of an estimate for the over-all effect without a frequency-based analysis. The following procedure for determining an over-all effective sound transmission loss is therefore confined to items 1, 2, and 3.

With regard to item 1 it has been illustrated in Reference 3, that laboratory measurements of sound transmission losses are also fairly representative for noise barriers in the field.

2/ ADJUSTMENTS FOR LOW SOUND TRANSMISSION LOSS



LOSSES IN SOUND PRESSURE ENERGY (CONCEPTUAL)

$\Delta L = L - L_b$....total sound waves

$\Delta B = L - L_d$....diffracted sound waves

$\Delta T = L - L_t$....transmitted sound waves

Figure 1, CONCEPTS OF BARRIER INSERTION LOSSES

Where:

ΔL = net barrier insertion loss, in dBA.

ΔB = geometric barrier insertion loss, in dBA, including a reduction for the removal of ground cover absorption.

ΔT = effective sound transmission loss of wall material, in dBA. (Refer to Chapter 3 of this report)

The combination of sound or noise levels on the receiver side of sound barriers is shown in Figure 1. With the definitions given, the following equation can be used to calculate a reduced net insertion loss, ΔL,

$$\Delta L = -10 \log \left[10^{-\Delta B/10} + 10^{-\Delta T/10}\right], \text{ dBA} \qquad (1)$$

This equation is derived by adding the sound pressure energy losses as follows:

$$10^{-\Delta B/10} + 10^{-\Delta T/10} = 10^{-\Delta L/10} = \text{total loss}$$

Instead of using Equation 1, the following table can be used to subtract a correction value from ΔB, so that $\Delta L = \Delta B - \varepsilon$. The correction ε is a function of the difference $(\Delta T - \Delta B)$.

TABLE 1, Correction ε to be subtracted from ΔB

$\Delta T - \Delta B$ (dBA)	Correction ε (dBA)
0	3.0
.5	2.8
1.0	2.5
1.5	2.3
2.0	2.1
2.5	1.9
3.0	1.8
4.0	1.5
5.0	1.2
6.0	1.0
7.0	.8
8.0	.6
9.0	.5
10.0	.4
12.5	.2
15.0	.1
17.5	.1
20.0	.0

Note: The corrections listed in Table 1 somewhat exceed the level of human perception which is of the order of $\pm$ 0.5 dBA

EXAMPLE:

ΔB = 12.0 dBA for a certain receiver location behind a barrier, obtained from current prediction methods, such as used in [2].

ΔT = 16.0 dBA	effective value for a thin wall corrugated panel, from a calculation based on laboratory test results (refer to Section 3).
ε = 1.5 dBA	from Table 1, value to be subtracted from ΔB.
ΔL = 12.0 - 1.5 = 10.5 dBA	result, a reduced value of the insertion loss of the barrier.

Once a suitable realistic value of the effective sound transmission loss, ΔT, is determined, the adjustment of the noise abatement, ΔB, is very easy. It can be done for each value of ΔB obtained from noise prediction calculations by subtracting the correction.

Low values of sound transmission loss, ΔT, mean that more noise is transmitted through the barrier wall which reduces the effectiveness of the barrier. This can be accounted for by reducing the quoted values for noise reduction or barrier insertion loss. In practical terms there is also the need to determine options of equally effective barriers of different materials, such as concrete and thin corrugated steel panels.

In this case equal performance depends on a difference in height. To be equally effective, concrete barriers can be built slightly lower in height than steel barriers. For typical critical receiver locations, height equivalencies can be established. The first calculated values (i.e., the computer output) of noise reduction for a certain barrier option pertain to solid concrete barriers which have always sufficient area mass density. For three different height options the values may be plotted, as shown in Figure 2, based on three computer print-outs: 9.9 dBA, 11 dBA, 12 dBA for 4 m, 4.5 m, and 5 m barrier heights, respectively.

The adjusted noise reduction values for a typical steel panel are plotted, in Figure 2, below the values 9.9, 11, and 12 dBA, using the corrections from Table 1. The dashed lines of the diagram indicate the method to determine height equivalencies for 10 dBA noise reduction. Note that the difference of equivalent heights increases with increasing values of barrier insertion loss, and the results are different for different receiver locations. The selection of locations which are most representative for establishing height equivalencies must be left to the designer, if he/she intends to determine an over-all height equivalency.

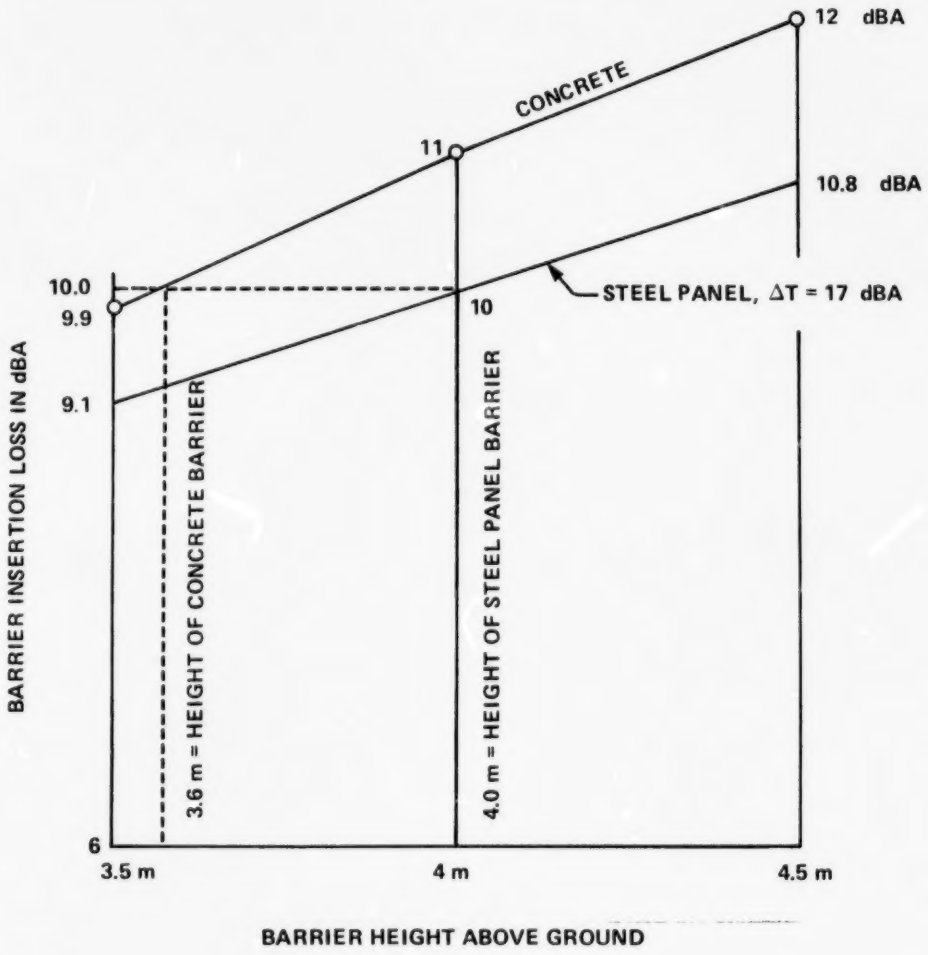


FIGURE 2. HEIGHT EQUIVALENCIES

Compare Figure 3 in [2]

3/ EFFECTIVE SOUND TRANSMISSION LOSS

a) Procedure for Corrugated Steel Panels

The net barrier insertion loss for a 1/3 octave frequency band "i" is calculated by the following equation:

$$\Delta L_i = -10 \log_{10} [10^{-\Delta B_i/10} + 10^{-\Delta T_i/10}] \qquad (2)$$

where

ΔL_i = net barrier insertion loss for frequency band, i, in dB.

ΔB_i = barrier insertion loss for 1/3 octave frequency band, i, as a function of Fresnell number and path length difference, in dB.

ΔT_i = sound transmission loss for 1/3 octave frequency band, i, from laboratory reports, in dB.

i = index for designating a frequency band.

Equation 2 is the same as Equation 1, but it is modified with regard to a particular band frequency, i.

To determine ΔB_i, the tables on Pages B-11 to B-71 in [5] can be used. For "infinitely" long barriers, blocking the line of sight from the source to the receiver, the pertinent values of these tables can be closely curve-fitted, resulting in the following equation:

$$\Delta B_i = 5 + 14.4 \times \exp\left[-0.175\,(2 - \log_{10} N_0)^{2.5}\right] \qquad (3)$$

where

$$N_0 = \frac{f_i\ \delta}{171.5} \quad \text{(refer to [5])}$$

f_i = band frequency, in Hz

δ = path length difference, in metres

Sound transmission loss values ΔT_i must be obtained from laboratory test reports based on ASTM Standard E 90-75. For corrugated steel panels currently being used or considered, laboratory reports from the following agencies are available:

1) Riverbank Acoustical Laboratories, Geneva, Illinois (Panels B and C, and
2) NRC, Division of Building Research, Ottawa, Ontario (Panel A). Refer also to Appendix A, which contains an example of such a report.

Values of ΔB_i and ΔL_i have been calculated for 1/3 octave band frequencies between 80 and 5000 Hz, for various path length differences, δ. The results for Panel A, Gauge 20 are shown in Table 2. The sound pressure energy related averages for all values ΔT_i, ΔB_i and ΔL_i are listed in a line near the bottom of each column, mainly for control purposes. Only the average value ΔT is used any further. For the purposes of comparison, the values of ΔB for 550 Hz are listed in the bottom line; they correspond to the values for noise abatement (Δ) in accordance with Reference 5.

TABLE 2

ΔL_i and ΔB_i Values

For Panel A

f_i Hz	ΔT_i	δ = 0.1 m		= 0.2 m		= 0.4 m		= 0.6 m		= 1.0 m		= 1.5 m	
		ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i
80	11	4.356	5.416	4.714	5.878	5.307	6.672	5.776	7.327	6.479	8.371	7.097	9.367
100	10	4.207	5.535	4.610	6.093	5.245	7.014	5.723	7.753	6.406	8.902	6.975	9.971
125	15	5.201	5.681	5.790	6.345	6.706	7.402	7.397	8.226	8.402	9.475	9.262	10.610
160	11	4.714	5.878	5.307	6.672	6.159	7.885	6.753	8.801	7.546	10.153	8.160	11.348
200	14	5.441	6.093	6.221	7.014	7.321	8.371	8.083	9.367	9.101	10.800	9.897	12.036
250	16	5.898	6.345	6.840	7.402	8.128	8.902	9.004	9.971	10.161	11.472	11.057	12.735
315	18	6.342	6.650	7.452	7.853	8.923	9.496	9.902	10.633	11.176	12.188	12.152	13.461
400	18	6.681	7.014	7.922	8.371	9.493	10.153	10.498	11.348	11.759	12.938	12.689	14.203
500	19	7.111	7.402	8.497	8.902	10.188	10.800	11.240	12.036	12.529	13.638	13.457	14.878
630	18	7.452	7.853	8.923	9.496	10.620	11.497	11.623	12.760	12.793	14.352	13.594	15.550
800	17	7.813	8.371	9.337	10.153	10.986	12.237	11.903	13.510	12.918	15.069	13.574	16.204
1000	19	8.497	8.902	10.188	10.800	11.977	12.938	12.960	14.203	14.039	15.709	14.734	16.771
1250	29	9.427	9.475	11.396	11.472	13.513	13.638	14.713	14.878	16.084	16.311	17.005	17.289
1600	35	10.139	10.153	12.214	12.237	14.362	14.400	15.545	15.594	16.859	16.926	17.716	17.798
2000	38	10.792	10.800	12.924	12.938	15.047	15.069	16.176	16.204	17.391	17.428	18.151	18.196
2500	39	11.465	11.472	13.625	13.638	15.688	15.709	16.745	16.771	17.842	17.875	18.496	18.535
3150	37	12.174	12.188	14.329	14.352	16.295	16.332	17.260	17.306	18.218	18.275	18.755	18.821
4000	40	12.929	12.938	15.055	15.069	16.905	16.926	17.772	17.798	18.590	18.621	19.015	19.050
5000	38	13.622	13.638	15.683	15.709	17.391	17.428	18.151	18.196	18.828	18.881	19.149	19.206
Energy Averages	16.2514	7.2517	7.8361	8.2654	9.0177	9.451	10.4687	10.198	11.437	11.152	12.757	11.877	13.851
Control:		7.2517		8.2656		9.4510		10.1980		11.1520		11.8770	
		7.5815		9.1420		11.0840		12.3330		13.9340		15.1590	
ΔB550 Hz= Equ. (3)													
Table in Ref. [5]		7.60		9.19		10.86		12.15		13.81		15.17	

TABLE 3
Values of $(L_i - \Delta L_i)$ and $(L_i - \Delta B_i)$

f_i	Traffic Spectrum measured	adjusted	δ = 0.1 m		= 0.2 m		= 0.4 m		= 0.6 m		= 1.0 m		= 1.5 m	
Hz	L_{i50}	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -	L_i -
	dB	dBA	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i	ΔL_i	ΔB_i
80	73.5	51.0	46.644	45.584	46.286	45.122	45.693	44.328	45.224	43.673	44.521	42.629	43.903	41.633
100	74.5	55.4	51.193	49.865	50.790	49.307	50.155	48.386	49.677	47.647	48.994	46.498	48.425	45.429
125	74.5	58.1	52.899	52.419	52.310	51.755	51.394	50.698	50.703	49.874	49.698	48.625	48.838	47.490
160	73.5	60.1	55.386	54.222	54.793	53.428	53.941	52.215	53.347	51.299	52.554	49.947	51.940	48.752
200	74.0	63.1	57.659	57.007	56.879	56.086	55.779	54.729	55.017	53.733	53.999	52.300	53.203	51.064
250	73.5	64.9	59.002	58.555	58.060	57.498	56.772	55.998	55.896	54.929	54.739	53.428	53.843	52.165
315	73.0	66.4	60.058	59.750	58.948	58.547	57.477	56.904	56.498	55.767	55.224	54.212	54.248	52.939
400	73.5	68.7	62.019	61.686	60.778	60.329	59.207	58.547	58.202	57.352	56.905	55.762	56.011	54.497
500	71.5	68.3	61.189	60.898	59.803	59.398	58.112	57.700	57.060	56.264	55.771	54.662	54.843	53.422
630	73.0	71.1	63.648	63.247	62.177	61.604	60.480	59.603	59.477	58.340	58.307	56.748	57.506	55.550
800	72.5	71.7	63.887	63.329	62.363	61.547	60.714	59.463	59.797	58.190	58.782	56.631	58.126	55.496
1000	71.5	71.5	63.003	62.598	61.312	60.700	59.523	58.562	58.540	57.297	57.461	55.791	56.766	54.729
1250	71.5	72.1	62.673	62.625	60.704	60.628	58.587	58.462	57.387	57.222	56.016	55.789	55.095	54.811
1600	68.5	69.5	59.361	59.347	57.286	57.263	55.138	55.100	53.955	53.906	52.641	52.574	51.784	51.702
2000	64.0	65.2	54.408	54.400	52.276	52.262	50.153	50.131	49.024	48.996	47.809	47.772	47.049	47.004
2500	60.5	61.8	50.335	50.328	48.175	48.162	46.122	46.091	45.055	45.029	43.958	43.925	43.304	43.265
3150	57.0	58.2	46.026	46.012	43.871	43.848	41.905	41.868	40.940	40.894	39.982	39.925	39.445	39.379
4000	54.0	55.0	42.071	42.062	39.945	39.931	38.095	38.074	37.228	37.202	36.410	36.379	35.985	35.950
5000	50.5	51.0	37.378	37.362	35.317	35.291	33.609	33.572	32.849	32.804	32.172	32.119	31.851	31.794
Energy rel. total(t)	84.513	79.942	72.024	71.661	70.572	70.056	68.937	68.181	67.969	66.978	66.817	65.479	66.017	64.342
$L_t - (L_t - \Delta L) = \Delta L$ actual			7.918		9.370		11.005		11.978		13.125		13.925	
$L_t - (L_t - \Delta B) = \Delta B$ actual				8.281		9.886		11.761		12.964		14.464		15.600

The second column in Table 3 contains a typical profile of sound pressure levels, L_i obtained from measurements of Hwy 401. These values can be regarded as typical for major expressways in Ontario. The third column contains the same sound levels, L_i but A-weighted, and these are the basis for further calculations in Table 3.

The calculated values in Table 2 are used to compute typical reduced traffic sound spectra from the given measured and A-weighted sound spectra in Column 3 of Table 3. The reduced values are listed as $(L_i - \Delta L_i)$ and $(L_i - \Delta B_i)$, where L_i is the A-weighted original sound level spectrum. The total noise levels, L_t from all the columns are listed near the bottom of Table 3. The last two lines of the table show the differences, namely:

1) ΔL_{actual} = actual net barrier insertion loss, in dBA, taking into account sound transmission.
2) ΔB_{actual} = actual noise abatement or insertion loss, not taking into account sound transmission.

The values ΔL_{actual} and ΔB_{actual} in Table 3 can be processed to calculate the effective sound transmission loss, ΔT_{eff}. For this purpose, Equation 1 can be rearranged;

$$\Delta T_{eff} = -10 \log_{10} [10^{-\Delta L \text{ actual}} - 10^{-\Delta B \text{ actual}}] \qquad (4)$$

The following values are obtained, quoted in dBA units:

δ = 0.1 m	ΔT_{eff} = 18.877	
δ = 0.2 m	ΔT_{eff} = 18.877	
δ = 0.4 m	ΔT_{eff} = 18.970	ΔT_{eff} = 18.9
δ = 0.6 m	ΔT_{eff} = 18.901	
δ = 1.0 m	ΔT_{eff} = 18.887	
δ = 1.5 m	ΔT_{eff} = 18.387	

As expected, ΔT_{eff} is independent from the path length difference, δ, and small differences are only indicative of the accuracy of the calculations.

Similar calculations as for the Panel A have been carried out for two other panels, B and C, for the same conditions.

The following results are obtained, rounded to the closest 1/10 dBA unit:

Panel A, Gauge 20: ΔT_{eff} = 18.9 dBA
Panel B, Gauge 22: ΔT_{eff} = 22.7 dBA
Panel C, Gauge 24: ΔT_{eff} = 20.9 dBA

It should be noted that these results are dependent on the following conditions:

1) The A-weighted traffic sound spectrum and level, typical for Hwy 401 traffic.
2) "Knife edge" and "infinitely" long barrier.
3) Sound reflective ground cover.

Note that the results are independent from the relative positions of noise source, receiver, and barrier top. They are also independent from any values of ΔT_i and L_i beyond the selected frequency band range of 80 to 5000 Hz, since the values of lower and higher frequencies have no measurable influence.

The results are surprising: the heavier panel, gauge 20 (0.91 mm) has the lowest transmission loss, compared to the lighter panel, gauge 22 (0.76 mm), and even lower than the lightest panel, gauge 24 (0.61 mm). An explanation may be forwarded in reference to Figure 3.

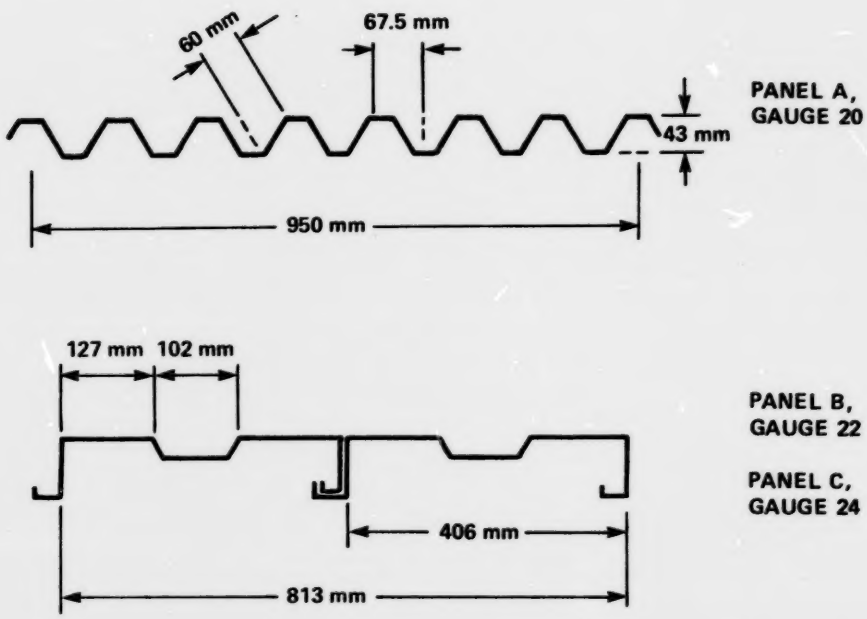


FIGURE 3. COMPARISON OF PANELS

Comparing the two profiles of steel panels, a relationship between the major dip frequency and shape dimension can be observed.

Panel	Critical Major "Dip" Frequency	Sound Wave Length	Flat part Shape Dimension
A (G 20)	800 Hz	42 mm	60 mm
C (G 24)	200 Hz	170 mm	127 mm

Observe that the critical major "dip" frequency of 800 Hz has a much larger influence on the effective sound transmission than the "dip" at 200 Hz.

The major dips in ΔT_i values occur at sound frequencies which cause resonance vibrations in the panel material. Therefore, smaller flat part shape dimensions must be correlated with smaller sound wave lengths, i.e., higher frequencies. Further, the Panel C surface is rigidly supported by its own edge ribs. This stiffens the flat portion of the panel. Both the lower critical frequency and the edge stiffness by the ribs seem to explain the superior performance of the Panels B and C in terms of sound transmission loss.

b) Sound Transmission Losses for Various Materials

Sound transmission losses of some non-corrugated flat-faced materials can be estimated by the field incidence mass law. These materials are the ones with higher mass densities, namely concrete, steel, brick, etc. For other flat-faced materials such as wood, plastic and fibre glass, the field incidence mass law cannot be applied without taking into account transmission loss dips at higher or medium frequencies. For more information, the reader is referred to Reference 6.

Sound transmission losses of corrugated thin materials (steel, aluminum, fibreglass) cannot be predicted with certainty, as they are usually affected by unpredictable low dips in transmission loss at critical frequencies. Therefore laboratory tests are always required.

Laboratory tests methods (such as described by ASTM E90-75) are used to measure random incidence sound transmission losses for 1/3 octave frequency bands. It has been illustrated that these measurements can be regarded as fairly representative of transmission losses happening in actual noise barrier installations in the field [3]. In actual fact, there are various corrections to be considered, but they are partly positive and partly negative and approximately cancel one another.

In all those cases of various materials the same procedure applies to arrive at an over-all effective sound transmission loss as it has been demonstrated above for corrugated steel panels.

In spite of the fact that a reliable effective over-all transmission loss can only be established by going through the procedure, approximate estimates of the effective sound transmissions, ΔT_{eff} is needed because the rigorous procedure demonstrated above is very tedious and time consuming. Such approximate engineering estimates are deemed possible for all materials which follow fully or partly the field incidence mass law, i.e., for flat-faced material with "dips" below or above frequencies outside the range of significant influence on the results of a rigorous procedure. Based on Table 3, the range of significant influence appears to be confined to frequencies from 200 Hz to 1600 Hz, beyond which the differences in sound levels become larger than 4 dBA.

For materials without significant "dips" between 125 Hz and 2000 Hz, the effective sound transmission loss can be estimated based on the sound pressure energy average of ΔT_i values from 200 Hz to 1600 Hz inclusive.

$$\Delta T_{eff} \cong -10 \log_{10} \left[\frac{1}{10} \sum_{i=1}^{10} 10^{-\Delta T_i} \right] \qquad (5)$$

where T_i = 1/3 octave band frequency sound transmission losses for band frequencies from 200 Hz (i = 1) to 1600 Hz (i=10)

The above-mentioned conditions are met by all flat panel materials made of steel, aluminum, and glass, and their values ΔT_i can be calculated by the field incidence mass law; from [7]:

$$\Delta T_i = 20 \log 10 (wf_i) - 47.4 \qquad (6)$$

where w = area density of panel material, in kg/m^2
f_i = band frequency, in Hz

Equations 6 and 5 do not apply for plywood. In accordance with [6], fir plywood with 5.7 kg/m^3 for thicknesses of about 20 mm and above, is governed by the plateau value of $\Delta T \cong 19$ dBA.

4/ CONTROL OF DEGRADATION OF NOISE BARRIER EFFECTIVENESS FROM SOUND TRANSMISSION LOSS

Instead of complicating acoustical design advice by taking into account the over-all effective sound transmission loss, ΔT_{eff} of all kinds of materials, as described in Chapter 2 of this report, there is the alternative to accept a certain minor degradation of barrier effectiveness and specify minimum values of sound transmission loss profiles. The following is a discussion of a proposed specification in accordance with prevailing conditions in Ontario.

Conditions:
Path length difference = 0.6 m
Tolerable degradation of $\Delta B < 1.0$ dBA
or < 8%

The specification may then be worded as follows:

Under normal circumstances, for current barrier heights in Ontario and normal receiver distances (i.e., path length differences of less than or equal to 0.6 m) the deterioration of noise abatement is less than 1 dBA, when the following specification is met.

1) "Determine the random incidence sound transmission loss of the panel material by a recognized laboratory test method such as ASTM E90-75.

   Based on a certified test report, the sound transmission losses for all 1/3 octave frequency bands from 80 Hz to 5000 Hz shall meet the following values, i.e., shall be equal or larger than the values listed in the following table."

1/3 Octave Band Frequency	Minimum Sound Transmission Loss
80 Hz	10 dB
100 "	10 "
125 "	11 "
160 "	12 "
200 "	14 "
250 "	16 "
315 "	18 "
400 "	18 "
500 "	19 "
over 500 "	19 "

"Panels which do not meet these values in one or two frequencies being short by one or two dB, may still be accepted, if the remaining values are sufficiently higher to counteract the violating dip. However, such panels must be evaluated by an acoustic expert before being accepted."

If the table values are used in the procedure shown in Chapter 3, the effective sound transmission loss would be ΔT_{eff} = 18.15 dBA. As the probability of such a material is very remote, the practical minimum ΔT_{eff} would be slightly larger, such as 18.9 dBA, as listed for Panel A. Figure 4 illustrates the effect of the specified minimum values and the various steel panels for a larger range of path lengths differences. Figure 4 also shows the degradations for all panel materials in percent of ΔB_{actual}.

These diagrams should provide some guidance for the acoustic designer when dealing with the aforementioned steel panels.

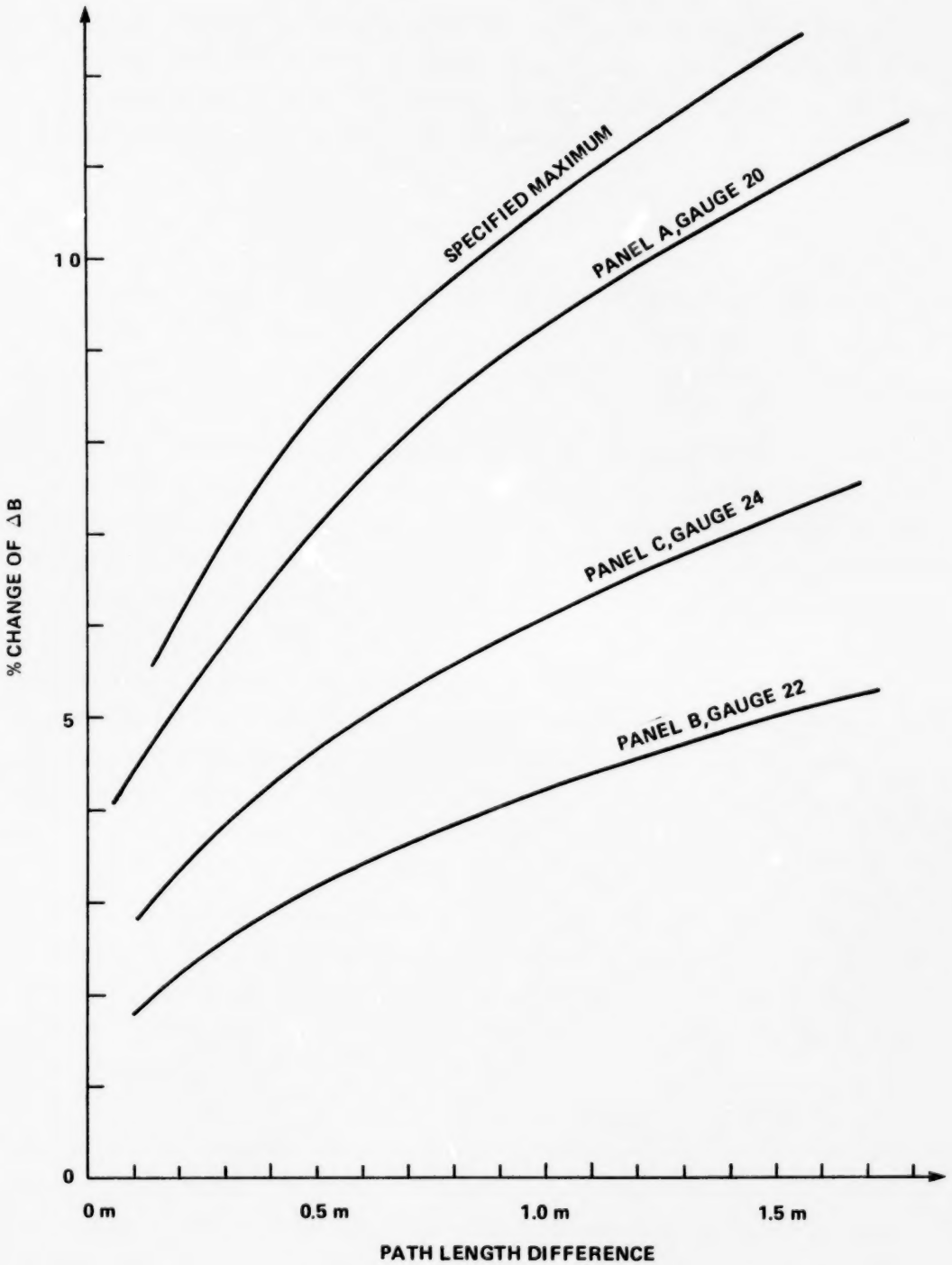


FIGURE 4. DEGRADATION OF PANEL MATERIALS

5/ CONCLUSIONS AND RECOMMENDATIONS

The most economical wall materials for traffic noise barriers are often corrugated thin panels with low area mass density and unfavorable resonance frequencies. Sound transmission through such materials can be significant, especially for high effective barriers.

Instead of excluding such materials from use in barrier construction, it is feasible to take their sound transmission into account and make it part of the design. The necessary sound transmission loss values for flat materials can always be obtained from laboratory tests or can be estimated for certain types of materials, such as concrete, brick, etc.

It has been shown that noise reduction values of sound barriers can be adjusted for sound transmission by a simple procedure. It is also possible to compensate for sound transmission by increasing the height of thin panel barrier walls. For typical Hwy 401 traffic conditions and long barriers with reflective ground cover, overall effective sound transmission losses have been calculated for various corrugated steel panels, and the lowest value of about 18.5 to 19 dBA should be the specified minimum. This would limit degradations of noise abatement to 1 dBA or less, based on barrier conditions with path length differences of about 0.6 m, representing normal conditions for Ontario. The effect for smaller or larger path length differences is also shown.

Acoustically, there is no reason to limit the gauge or ask for a minimum thickness of steel panel material, and panels of gauge 22 or 24 may perform satisfactorily. This may lead to considerable savings in steel without adverse acoustical effects, if sound transmission is being controlled as suggested.

The methods of determining or estimating sound transmission losses proposed in this report must be understood as engineering solutions pertaining to rather complex problems of sound wave transmission through barrier wall materials, combined with sound wave diffraction over the

barrier top, and in conjunction with complex traffic noise spectra. Such engineering solutions are based on simplifying assumptions which must be carefully evaluated by expert knowledge, too difficult to quantify or explain in the report.

With regard to design economy, an over-all cost-effectiveness should be considered. Differences in costs from increasing the barrier height or selecting superior materials must be weighted against the benefits obtained by increasing the barrier effectiveness in terms of noise reduction by a few decibels.

APPENDIX A

RIVERBANK ACOUSTICAL LABORATORIES

OF IIT RESEARCH INSTITUTE

1512 BATAVIA AVE., BOX 189
GENEVA, ILLINOIS 60134
312/232-0104

FOUNDED 1918 BY WALLACE CLEMENT SABINE

REPORT

FOR: Armco Steel Corporation

Sound Transmission Loss
Test TL 76-193

ON: 24 Gauge Sculptured STEELOX

CONDUCTED: 19 July 1976

TEST METHOD: Unless otherwise designated, the measurements reported below were made with all facilities and procedures in explicit conformity with the American Society for Testing and Materials Designations E 90-75 and E413-73, as well as other pertinent standards.

DESCRIPTION OF THE SPECIMEN: The test specimen was constructed directly into the laboratory test opening 14 feet (4.3 m) wide and 9 feet (2.7 m) high. Two wide flanged 10 x 17 sections were vertically set into the test opening, spaced 8 feet (2.4 m) apart, 3 feet (0.9 m) from each end and attached to the top and bottom of the test frame. On one side, panels each 3 inches (76.2 mm) deep, 16 inches (0.41 m) wide and cut to 167-3/4 inches (4.3 m) were horizontally orientated and interlocked together to form a continuous wall. The flat portions of the panels were placed in contact with the vertical members. The top section was cut to fit the test opening. These panels were attached to the vertical members with 2 screws at each vertical member location. No caulking was used at the joints. The perimeter of the specimen was sealed to the test opening. The specimen, less vertical members weighed 205 pounds (93.0 kg), an average of 1.6 pounds per sq ft (7.8 kg/m^2). A detailed drawing of the construction is in the laboratory file. The transmission area, S, used in the computations was 126 sq ft (11.7 m^2).

RESULTS OF MEASUREMENTS: Sound transmission loss values are tabulated at the twenty four frequencies. An explanation of the sound transmission class rating, a graphic presentation of the data, and additional information appear on the following pages.

FREQUENCY, Hertz (cps)	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
TRANSMISSION LOSS, dB	8*	10*	18*	15	10	13	11	14	19	21	24	24	25	25	24	25	26	30	30	33	32	33	35	35
DEFICIENCIES							3	3	1	2		1	1	2	4	3	2							
SOUND TRANSMISSION CLASS 24											$\Delta\bar{T}$ = 17.2 dB							range for ΔT_i						

*The transmission loss at these frequencies do not conform to ASTM E90.

Approved _____ Submitted by _____

Dr. Renny S. Norman
Manager

D. A. Zedonis
Assistant Research Engr.

THE RESULTS REPORTED ABOVE APPLY ONLY TO THE SPECIFIC SAMPLE SUBMITTED FOR MEASUREMENT. NO RESPONSIBILITY IS ASSUMED FOR PERFORMANCE OF ANY OTHER SPECIMEN.

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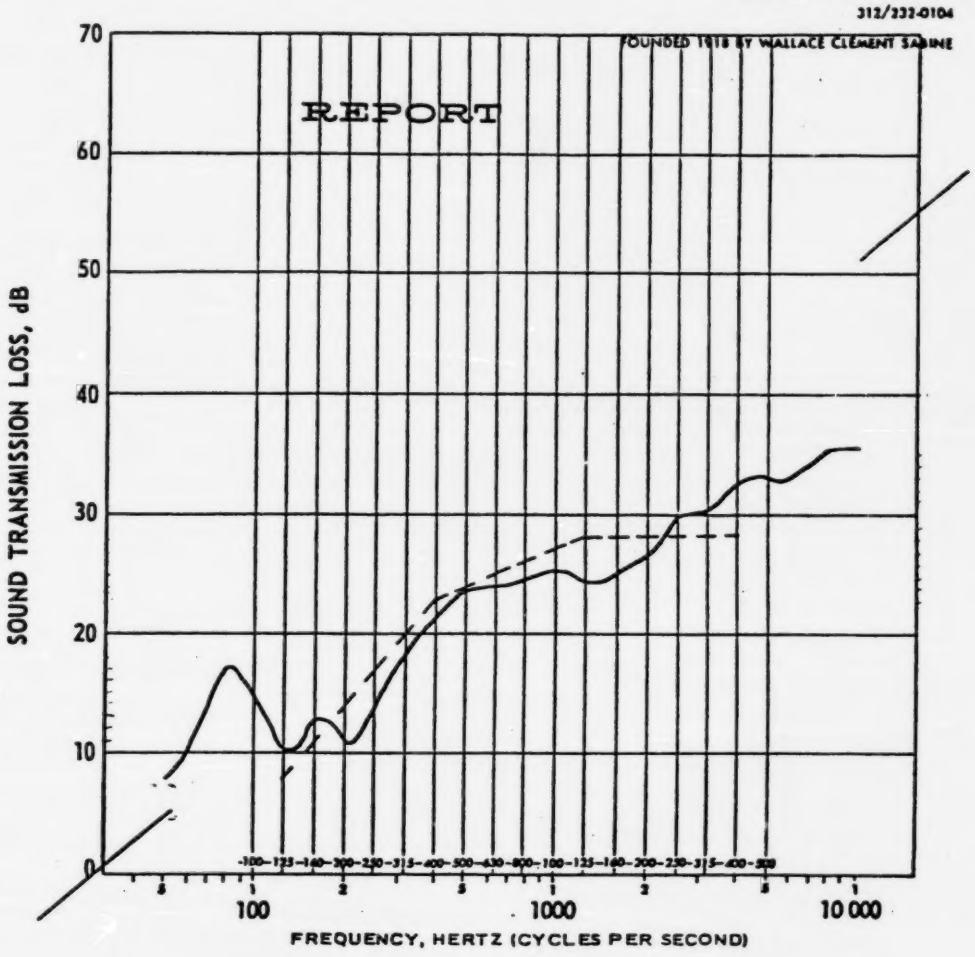
REPORT



PAGE 2 OF 3 , TL 76-193 THIS PAGE ALONE IS NOT A COMPLETE REPORT

THE SOUND TRANSMISSION LOSS OF THE TESTED SPECIMEN IS SHOWN BY THE CURVED LINE IN THE ABOVE GRAPH. THE BROKEN LINE IS THE LIMITING SOUND TRANSMISSION CLASS CONTOUR. THE GRAPH WAS PREPARED ON CODEX PAPER NO. 31, 462.

THE THEORETICAL TRANSMISSION LOSS OF THAT LIMP MASS HAVING THE SAME WEIGHT PER SQUARE FOOT AS THE SPECIMEN CAN BE LOCATED BY DRAWING A STRAIGHT LINE BETWEEN THE TWO SLASH MARKS ON THE EDGES OF THE GRID. THIS WAS DERIVED FROM THE EQUATION: TL = 20 LOG W + 20 LOG F - 33, WHERE W IS WEIGHT IN POUNDS PER SQUARE FOOT, AND F IS FREQUENCY IN HERTZ (CYCLES PER SECOND).

THE RESULTS REPORTED ABOVE APPLY ONLY TO THE SPECIFIC SAMPLE SUBMITTED FOR MEASUREMENT. NO RESPONSIBILITY IS ASSUMED FOR PERFORMANCE OF ANY OTHER SPECIMEN.

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REPORT

The airborne sound transmission loss (TL) of a specimen is the ratio, expressed in decibels, (dB) of the sound power incident upon the specimen to the sound power transmitted through and radiated by the specimen when the sound fields on both sides are diffuse.

These measurements were made using a one-third octave band of pink noise, swept in fifteen minutes from 100 to 5000 Hertz (cycles per second). Two such runs were made, with a system interchange between. During each run the ratio of sound pressure levels in the two rooms is automatically and directly recorded graphically. The final results are obtained with a resultant precision better than a 90% confidence limits of $\pm$ 1 decibel.

The Sound Transmission Class (STC) is computed in accordance with ASTM E90-70 and E413-73. This number is intended to be used as a preliminary estimate of the acoustical properties of the specimen. Ultimate decisions should always be based upon the entire TL curve or values at all test frequencies.

Whenever a filler wall is used in mounting a specimen, the sound power transmitted through that wall is calculated and incorporated into the measured results before reporting.

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